Amendments to the Claims

Please amend the claims as presented below in the Listing of Claims, which replace all prior versions and listings of claims in this application. Please cancel claim 4, and amend the claims as follows:

Listing of Claims

1. (Currently Amended) A method of performing spatial processing at a receiver in a wireless multiple-input multiple-output (MIMO) communication system, comprising:

obtaining a plurality of received symbol streams for a plurality of data symbol streams sent via a plurality of spatial channels of a MIMO channel in the wireless MIMO communication system, wherein spatial processing is performed at a transmitter with steering vectors, which are estimates of transmitter steering vectors required to orthogonalize the plurality of spatial channels;

receiving orthogonal pilot transmissions from a plurality of antennas at the transmitter;

obtaining an estimate of a channel response matrix for the MIMO channel, wherein the estimated channel response matrix is obtained based on the received orthogonal pilot transmissions; and

performing spatial processing on the plurality of received symbol streams with a spatial filter to obtain a plurality of filtered symbol streams, which are estimates of the plurality of data symbol streams, wherein the spatial filter has a response derived based on a minimum mean square error (MMSE) criterion that minimizes mean square error between the plurality of filtered symbol streams and the plurality of data symbol streams, wherein the MMSE criterion is given as:

$$\min_{(\underline{\mathbf{W}})} E[(\underline{\mathbf{W}}\underline{\mathbf{r}}-\underline{\mathbf{s}})^{H}(\underline{\mathbf{W}}\underline{\mathbf{r}}-\underline{\mathbf{s}})],$$

where $\underline{\mathbf{s}}$ is a vector for the plurality of data symbol streams,

where $\underline{\mathbf{r}}$ is a vector for the plurality of received symbol streams,

$\underline{\mathbf{W}}$ is a matrix for the spatial filter,

$(\underline{\mathbf{W}}\underline{\mathbf{r}}-\underline{\mathbf{s}})^{H}$ denotes the Hermitian or the conjugate transpose of $(\underline{\mathbf{W}}\underline{\mathbf{r}}-\underline{\mathbf{s}})$, and

$E[x]$ is an expected value of x.

2. (Original) The method of claim 1, further comprising:

scaling the plurality of filtered symbol streams to obtain a plurality of recovered symbol streams, which are normalized estimates of the plurality of data symbol streams.

3. (Currently Amended) The method of claim 1, wherein the spatial processing is performed in accordance with the following formula:

$\tilde{\mathbf{s}} = \mathbf{W}\mathbf{r}$,

where ~~$\mathbf{r}$ is a vector for the plurality of received symbol streams,~~

~~$\mathbf{W}$ is a matrix for the spatial filter, and~~

$\tilde{\mathbf{s}}$ is a vector for the plurality of filter symbol streams.

4-6. (Cancelled)

7. (Currently Amended) ~~The method of claim 1~~ A method of performing spatial processing at a receiver in a wireless multiple-input multiple-output (MIMO) communication system, comprising:

obtaining a plurality of received symbol streams for a plurality of data symbol streams sent via a plurality of spatial channels of a MIMO channel in the wireless MIMO communication system, wherein spatial processing is performed at a transmitter with steering vectors, which are estimates of transmitter steering vectors required to orthogonalize the plurality of spatial channels;

receiving orthogonal pilot transmissions from a plurality of antennas at the transmitter;

obtaining an estimate of a channel response matrix for the MIMO channel, wherein the estimated channel response matrix is obtained based on the received orthogonal pilot transmissions; and

performing spatial processing on the plurality of received symbol streams with a spatial filter to obtain a plurality of filtered symbol streams, which are estimates of the plurality of data symbol streams, wherein the spatial filter has a response derived based on a minimum mean square error (MMSE) criterion that minimizes mean square error between the plurality of filtered symbol streams and the plurality of data symbol streams, wherein the spatial filter response is derived in accordance with the following formula:

$$\underline{\mathbf{W}} = \hat{\underline{\mathbf{V}}}^{H}\hat{\underline{\mathbf{H}}}^{H}[\hat{\underline{\mathbf{H}}}\hat{\underline{\mathbf{V}}}\hat{\underline{\mathbf{V}}}^{H}\hat{\underline{\mathbf{H}}}^{H} + \underline{\varphi}_{nn}]^{-1} ,$$

where $\underline{\mathbf{W}}$ is the spatial filter response,

$\hat{\underline{\mathbf{V}}}$ is a matrix of the steering vectors used for spatial processing at the transmitter,

$\hat{\underline{\mathbf{H}}}$ is the estimated channel response matrix,

$\hat{\underline{\mathbf{V}}}^{H}$ and $\hat{\underline{\mathbf{H}}}^{H}$ denote the Hermitian or conjugate transpose of $\hat{\mathbf{V}}$ and $\hat{\mathbf{H}}$ respectively, and

$\underline{\varphi}_{nn}$ is an autocovariance matrix of noise at the receiver.

8. (Original) The method of claim 1, further comprising:
receiving a steered pilot via the plurality of spatial channels; and
deriving the spatial filter response based on the received steered pilot.

9. (Original) The method of claim 1, wherein the plurality of data symbol streams are spatially processed at the transmitter with a plurality of steering vectors obtained by decomposing an estimate of a channel response matrix for the MIMO channel.

10. (Original) The method of claim 1, wherein the MIMO system implements orthogonal frequency division multiplexing (OFDM), and wherein the spatial processing is performed for each of a plurality of subbands.

11. (Currently Amended) A receiver in a wireless multiple-input multiple-output (MIMO) communication system, comprising:

a receiver unit operative to receive orthogonal pilot transmissions from a plurality of antennas at a transmitter, the receiver unit also operative to obtain a plurality of received symbol streams for a plurality of data symbol streams sent via a plurality of spatial channels of a MIMO channel in the wireless MIMO communication system, wherein spatial processing is performed at a transmitter with steering vectors, which are estimates of transmitter steering vectors required to orthogonalize the plurality of spatial channels;

a channel estimator operative to obtain an estimate of a channel response matrix for the

MIMO channel, wherein the estimated channel response matrix is obtained based on the received orthogonal pilot transmissions; and,

a spatial filter operative to spatially process the plurality of received symbol streams to obtain a plurality of filtered symbol streams, which are estimates of the plurality of data symbol streams, wherein the spatial filter has a response derived based on a minimum mean square error (MMSE) criterion that minimizes mean square error between the plurality of filtered symbol streams and the plurality of data symbol streams, wherein the MMSE criterion is given as:

$$\min_{(\underline{\mathbf{W}})} E[(\underline{\mathbf{W}}\underline{\mathbf{r}} - \underline{\mathbf{s}})^H (\underline{\mathbf{W}}\underline{\mathbf{r}} - \underline{\mathbf{s}})],$$

where $\underline{\mathbf{s}}$ is a vector for the plurality of data symbol streams,

where $\underline{\mathbf{r}}$ is a vector for the plurality of received symbol streams,

$\underline{\mathbf{W}}$ is a matrix for the spatial filter,

$(\underline{\mathbf{W}}\underline{\mathbf{r}} - \underline{\mathbf{s}})^H$ denotes the Hermitian or the conjugate transpose of $(\underline{\mathbf{W}}\underline{\mathbf{r}} - \underline{\mathbf{s}})$, and

$E[x]$ is an expected value of x.

12. (Original) The receiver of claim 11, further comprising:

a scaling unit operative to scale the plurality of filtered symbol streams to obtain a plurality of recovered symbol streams, which are normalized estimates of the plurality of data symbol streams.

13. (Cancelled)

14. (Previously Presented) The receiver of claim 11, wherein the wireless MIMO communication system implements orthogonal frequency division multiplexing (OFDM), and wherein the spatial filter is operative to perform spatial processing for each of a plurality of subbands.

15. (Currently Amended) A receiver apparatus in a wireless multiple-input multiple-output (MIMO) communication system, comprising:

means for obtaining a plurality of received symbol streams for a plurality of data symbol streams sent via a plurality of spatial channels of a MIMO channel in the wireless MIMO communication system, wherein spatial processing is performed at a transmitter with steering vectors, which are estimates of transmitter steering vectors required to orthogonalize the plurality of spatial channels;

means for receiving orthogonal pilot transmissions from a plurality of antennas at the transmitter;

means for obtaining an estimate of a channel response matrix for the MIMO channel, wherein the estimated channel response matrix is obtained based on the received orthogonal pilot transmissions; and

means for performing spatial processing on the plurality of received symbol streams with a spatial filter to obtain a plurality of filtered symbol streams, which are estimates of the plurality of data symbol streams, wherein the spatial filter has a response derived based on a minimum mean square error (MMSE) criterion that minimizes mean square error between the plurality of filtered symbol streams and the plurality of data symbol, wherein the MMSE criterion is given as:

$$\min_{(\underline{\mathbf{W}})} E[(\underline{\mathbf{W}}\underline{\mathbf{r}}-\underline{\mathbf{s}})^H(\underline{\mathbf{W}}\underline{\mathbf{r}}-\underline{\mathbf{s}})]\ ,$$

where $\underline{\mathbf{s}}$ is a vector for the plurality of data symbol streams,

where $\underline{\mathbf{r}}$ is a vector for the plurality of received symbol streams,

$\underline{\mathbf{W}}$ is a matrix for the spatial filter,

$(\underline{\mathbf{W}}\underline{\mathbf{r}}-\underline{\mathbf{s}})^H$ denotes the Hermitian or the conjugate transpose of $(\underline{\mathbf{W}}\underline{\mathbf{r}}-\underline{\mathbf{s}})$, and

$E[x]$ is an expected value of x.

16. (Original) The receiver apparatus of claim 15, further comprising:

means for scaling the plurality of filtered symbol streams to obtain a plurality of recovered symbol streams, which are normalized estimates of the plurality of data symbol streams.

17. (Cancelled)

18. (Previously Presented) The receiver apparatus of claim 15, wherein the wireless MIMO communication system implements orthogonal frequency division multiplexing (OFDM),

and wherein the spatial processing is performed for each of a plurality of subbands.

19. (Currently Amended) A method of performing spatial processing at a transmitter in a wireless multiple-input multiple-output (MIMO) communication system, comprising:

obtaining a plurality of data symbol streams for transmission on a plurality of spatial channels of a MIMO channel in the wireless MIMO communication system;

obtaining an estimate of a plurality of steering vectors, wherein the plurality of steering vectors is based on received orthogonal pilot transmissions; and

performing spatial processing on the plurality of data symbol streams with the plurality of steering vectors, one steering vector for each data symbol stream, to obtain a plurality of transmit symbol streams for transmission from a plurality of transmit antennas, wherein the plurality of steering vectors are estimates of transmitter steering vectors required to orthogonalize the plurality of spatial channels, and

wherein the plurality of data symbol streams are recovered at a receiver with a spatial filter having a response derived based on a minimum mean square error (MMSE) criterion that minimizes mean square error between a plurality of filtered symbol streams from the spatial filter and the plurality of data symbol streams, wherein the MMSE criterion is given as:

$$\min_{(\underline{\mathbf{W}})} E[(\underline{\mathbf{W}}\underline{\mathbf{r}} - \underline{\mathbf{s}})^H (\underline{\mathbf{W}}\underline{\mathbf{r}} - \underline{\mathbf{s}})] ,$$

where $\underline{\mathbf{s}}$ is a vector for the plurality of data symbol streams,

where $\underline{\mathbf{r}}$ is a vector for the plurality of received symbol streams,

$\underline{\mathbf{W}}$ is a matrix for the spatial filter,

$(\underline{\mathbf{W}}\underline{\mathbf{r}} - \underline{\mathbf{s}})^H$ denotes the Hermitian or the conjugate transpose of $(\underline{\mathbf{W}}\underline{\mathbf{r}} - \underline{\mathbf{s}})$, and

$E[x]$ is an expected value of x.

20. (Original) The method of claim 19, wherein the spatial processing is performed in accordance with the following formula:

$$\underline{\mathbf{x}} = \hat{\underline{\mathbf{V}}}\underline{\mathbf{s}} ,$$

where $\underline{\mathbf{s}}$ is a vector for the plurality of data symbol streams,

$\underline{\hat{\mathbf{V}}}$ is a matrix for the plurality of steering vectors, and

$\underline{\mathbf{x}}$ is a vector for the plurality of transmit symbol streams.

21. (Original) The method of claim 19, wherein the plurality of steering vectors are obtained by decomposing an estimate of a channel response matrix for the MIMO channel.

22. (Previously Presented) The method of claim 19, wherein the wireless MIMO communication system is a time division duplex (TDD) system, wherein the plurality of data symbol streams are transmitted on a first link of the MIMO channel, and wherein the plurality of steering vectors are derived based on an estimate of a second link of the MIMO channel.

23. (Original) The method of claim 22, further comprising:

obtaining an estimate of a channel response matrix for the second link; and

decomposing the estimated channel response matrix for the second link to obtain the plurality of steering vectors used for the first link.

24. (Original) The method of claim 22, further comprising:

receiving a steered pilot via a plurality of spatial channels of the second link; and

deriving the plurality of steering vectors used for the first link based on the received steered pilot.

25. (Original) The method of claim 19, wherein the MIMO system implements orthogonal frequency division multiplexing (OFDM), and wherein the spatial processing is performed for each of a plurality of subbands.

26. (Currently Amended) A transmitter in a wireless multiple-input multiple-output (MIMO) communication system, comprising:

a transmit data processor operative to process a plurality of data streams and provide a plurality of data symbol streams for transmission on a plurality of spatial channels of a MIMO channel in the wireless MIMO communication system;

an estimator operative to obtain an estimate of a plurality of steering vectors, wherein the plurality of steering vectors is based on received orthogonal pilot transmissions; and

a transmit spatial processor operative to perform spatial processing on the plurality of data symbol streams with the plurality of steering vectors, one steering vector for each data symbol stream, to obtain a plurality of transmit symbol streams for transmission from a plurality of transmit antennas, wherein the plurality of steering vectors are estimates of transmitter steering vectors required to orthogonalize the plurality of spatial channels, and

wherein the plurality of data symbol streams are recovered at a receiver with a spatial filter having a response derived based on a minimum mean square error (MMSE) criterion that minimizes mean square error between a plurality of filtered symbol streams from the spatial filter and the plurality of data symbol streams, wherein the MMSE criterion is given as:

$$\min_{(\underline{\mathbf{W}})} E[(\underline{\mathbf{W}}\underline{\mathbf{r}}-\underline{\mathbf{s}})^H(\underline{\mathbf{W}}\underline{\mathbf{r}}-\underline{\mathbf{s}})],$$

where $\underline{\mathbf{s}}$ is a vector for the plurality of data symbol streams,

where $\underline{\mathbf{r}}$ is a vector for the plurality of received symbol streams,

$\underline{\mathbf{W}}$ is a matrix for the spatial filter,

$(\underline{\mathbf{W}}\underline{\mathbf{r}}-\underline{\mathbf{s}})^H$ denotes the Hermitian or the conjugate transpose of $(\underline{\mathbf{W}}\underline{\mathbf{r}}-\underline{\mathbf{s}})$, and

$E[x]$ is an expected value of x.

27. (Previously Presented) The transmitter of claim 26, wherein the wireless MIMO communication system is a time division duplex (TDD) system, wherein the plurality of data symbol streams are transmitted on a first link of the MIMO channel, and wherein the plurality of steering vectors are derived based on an estimate of a second link of the MIMO channel.

28. (Original) The transmitter of claim 27, further comprising:

a channel estimator operative to obtain an estimate of a channel response matrix for the second link; and

a matrix computation unit operative to decompose the estimated channel response matrix to obtain the plurality of steering vectors used for the first link.

29. (Original) The transmitter of claim 27, further comprising:

a channel estimator operative to obtain a channel response estimate for a plurality of spatial channels of the second link based on a steered pilot received via the plurality of spatial channels of the second link, and wherein the plurality of steering vectors used for the first link are derived based on the channel response estimate for the plurality of spatial channels of the second link.

30. (Currently Amended) A transmitter apparatus in a wireless multiple-input multiple-output (MIMO) communication system, comprising:

means for obtaining a plurality of data symbol streams for transmission on a plurality of spatial channels of a MIMO channel in the wireless MIMO communication system

means for obtaining an estimate of a plurality of steering vectors, wherein the plurality of steering vectors is based on received orthogonal pilot transmissions; and

means for performing spatial processing on the plurality of data symbol streams with the plurality of steering vectors, one steering vector for each data symbol stream, to obtain a plurality of transmit symbol streams for transmission from a plurality of transmit antennas, wherein the plurality of steering vectors are estimates of transmitter steering vectors required to orthogonalize the plurality of spatial channels, and

wherein the plurality of data symbol streams are recovered at a receiver with a spatial filter having a response derived based on a minimum mean square error (MMSE) criterion that minimizes mean square error between a plurality of filtered symbol streams from the spatial filter and the plurality of data symbol streams, wherein the MMSE criterion is given as:

$$\min_{(\underline{\mathbf{W}})} E[(\underline{\mathbf{W}}\underline{\mathbf{r}} - \underline{\mathbf{s}})^H (\underline{\mathbf{W}}\underline{\mathbf{r}} - \underline{\mathbf{s}})],$$

where $\underline{\mathbf{s}}$ is a vector for the plurality of data symbol streams,

where $\underline{\mathbf{r}}$ is a vector for the plurality of received symbol streams,

$\underline{\mathbf{W}}$ is a matrix for the spatial filter,

$(\underline{\mathbf{W}}\underline{\mathbf{r}} - \underline{\mathbf{s}})^H$ denotes the Hermitian or the conjugate transpose of $(\underline{\mathbf{W}}\underline{\mathbf{r}} - \underline{\mathbf{s}})$, and

$E[x]$ is an expected value of x.

31. (Previously Presented) The transmitter apparatus of claim 30, wherein the wireless MIMO communication system is a time division duplex (TDD) system, wherein the plurality of data symbol streams are transmitted on a first link of the MIMO channel, and

wherein the plurality of steering vectors are derived based on an estimate of a second link of the MIMO channel.

32. (Original) The transmitter apparatus of claim 31, further comprising:

means for obtaining an estimate of a channel response matrix for the second link; and

means for decomposing the estimated channel response matrix for the second link to obtain the plurality of steering vectors used for the first link.

33. (Original) The transmitter apparatus of claim 31, further comprising:

means for receiving a steered pilot via a plurality of spatial channels of the second link; and

means for deriving the plurality of steering vectors used for the first link based on the received steered pilot.

34. (Previously Presented) The transmitter apparatus of claim 30, wherein the wireless MIMO communication system implements orthogonal frequency division multiplexing (OFDM), and wherein the spatial processing is performed for each of a plurality of subbands.

35. (Previously Presented) The method of claim 1, further comprising deriving the spatial filter response based on the estimated channel response matrix.

36. (Previously Presented) The receiver of claim 11, further comprising a matrix computation unit operative to derive the spatial filter response based on the estimated channel response matrix.

37. (Previously Presented) The receiver apparatus of claim 15, further comprising means for deriving the spatial filter response based on the estimated channel response matrix.